'Improvements to the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Calibration System

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As a continuing effort to increase the calibration accuracy of the AVIRIS data a number of recent improvements have been implemented and are in the process of being tested during the 1994 flight season. These include the following innovations: A direct observation of a laboratory radiance standard is now used to double check the wide field-of-view calibration via an integrating sphere source. Launch site field calibration of the AVIRIS sensor is now being planned to augment the laboratory and in flight calibration, Modification to a dry air conditioning unit has been made to enable ground calibration at flight operating temperatures. Onc hundred lines of dark imagery has been added to the end of each flight line to assist in the analysis and removal of residu al coherent noise. The intensity of the onboard calibration lamp has been modified to improve response in the blue end of the spectrum. Novel spectral filters have been installed in the onboard calibration source.

INTRODUCTION

AVIRIS is an airborne sensor which measures high spatial resolution image data of the earth in 224 spectral channels in four spectrometers (A, B, C, and D) covering the range from 380 to 2500 nm. These data are spatially, spectrally and radiometrically calibrated (Vane, 1987, Chrien 1990, Chrien 1993 b). Modifications to AVIRIS that have resulted in substantial improvements in signal-to-noise ratio, calibration accuracy and operability of the sensor (Chrien, 1991, Chrien 1993a). Validation experiments arc conducted to verif y instrument performance and calibration in flight (Green, 1993a)

This paper describes the recent modifications to the AVIRIS instrument and support equ ipment that arc intended to further improve the quality of the AVIRIS data,

CALIBRATION REQUIREMENT

Imaging spectrometers are used to measure tfrc contiguous spectral signature of the upwelling radiance reflected and emitted from the surface of the earth and its atmosphere. The information contained in this data is in general a non-linear mixture of atmospheric molecular absorption and particle scattering signatures, surface reflected molecular absorption signatures and bidirectional reflectance properties and source spectral characteristics such as solar spectral radiance and surface temperatures. The scientific study of any onc of these effects requires a separation of these complex interactions.

The instrument calibration of an imaging spectrometer removes an additional (and unnecessary) complication to non-linear unmixing problem discussed above. In general, the requirement for calibration accuracy is determined by the tolerance of unmixing algorithms to residual calibration errors. This tolerance decreases as the signal-to-noise ratio of an imaging spectrometer increases in order to avoid unmixing that is instrument calibration error limited.

Recent improvements in both the signal-to-noise ratio of the AVIRIS instrument and tbc unmixing algorithms applied to AVIRIS data have prompted are-evaluation of its calibration requirements. Of primary interest arc improvements to the current instrument radiomctric accuracy of 5% absolute and spectra] accuracy of 1 to 2 nanometers.

CALIBRATION SYSTEM MODIFICATIONS

Modifications to the AVIRIS instrument arc governed b y a simple philosophy of incremental improvement tempered by risk aversion. Improvements are made only when significant payoff to the science capability and system reliability have been identified.

Radiometric Calibration

AVIRIS radiometric calibration is based upon the radiance standard constructed out of a calibrated reflectance panel and an irradiance standard lamp (Chrien, 1990). A spectroradiometer is used to transfer this radiance to a large integrating sphere which has uniform output over the 30 degree field-of-view of the AVIRIS scan mirror. The error associated with the intermediate calibration and radiometric stability of the integrating sphere is estimated to bc 1.1%.

Direct observation of the radiance target has been has been proposed as a method for eliminating this error source. An early attempt at this revealed a significant increase in stray light from the irradiance lamp. An investigation of scattered light sources has led to a radiance target design which uscs baffles and an off-axis look angle.

An additional requirement for the direct radiance standard was that it bc field portable. The desire was to have the capability to place a ground based radiometric calibration on the AVIRIS instrument while it is on deployment away from JPL.

Onc of the dry air units used to protect AVIRIS from humidity and condensation was modified to emit cold (approximately 10°C) dry air, A field calibration with an ambient instrument temperature at 10"C is currently planned for the 1994 flight season,

End of Run Dark Images

The AVIRIS instrument now records 100 lines of dark imagery at the end of each run of data. The fore-optics shutter is closed during this time as it is during end-of-line dark measurements. It is expected that this dark image will provide a data set on which to base coherent noise level measurements and to enable the construction of coherent noise filters for the data. A high resolution counter (H RC) has been added to the engineering telemetry to measure the number of instrument clock cycles between successive lines (which varies duc to roll correction). The high resolution counter provides a way to time code detector reads from line to line and may prove useful in filtering time dependent noise sources.

Onboard Calibration Lamp

The radiometric response of the four AVIRIS spectrometers arc monitored using an onboard calibration source. Light from this source is used to illuminate the back side of the closed fore-optics shutter prior to and immediately after each data run .The signal from the onboard calibrator can be used to compensate for tfrc minor changes in radiometric response during operation at flight temperatures and pressures (Green, 1993 b). In order to improve the utility of this method, a brighter tungsten halogen lamp has been installed in the onboard calibrator. Additional color balancing filters were also added to avoid saturating the AVIRIS channels nearest the

1.0 micron wavelengths. A comparison of the spectral response of the lamp is shown in Figure 1.

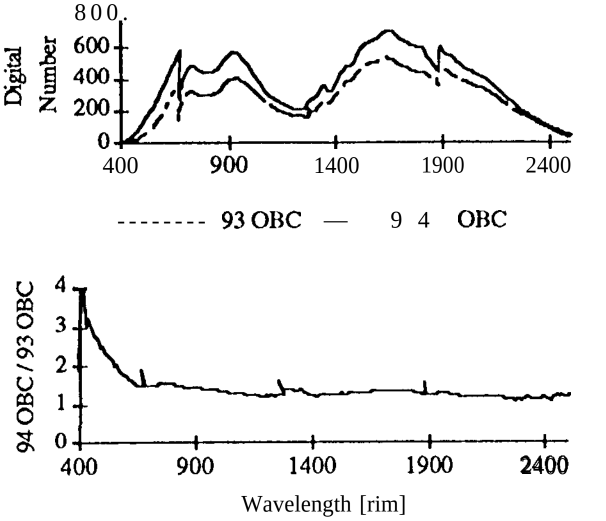

Figure 1.
Raw onboard calibrator signal from 1993 and 1994 and ratio showing signal improvement factor.

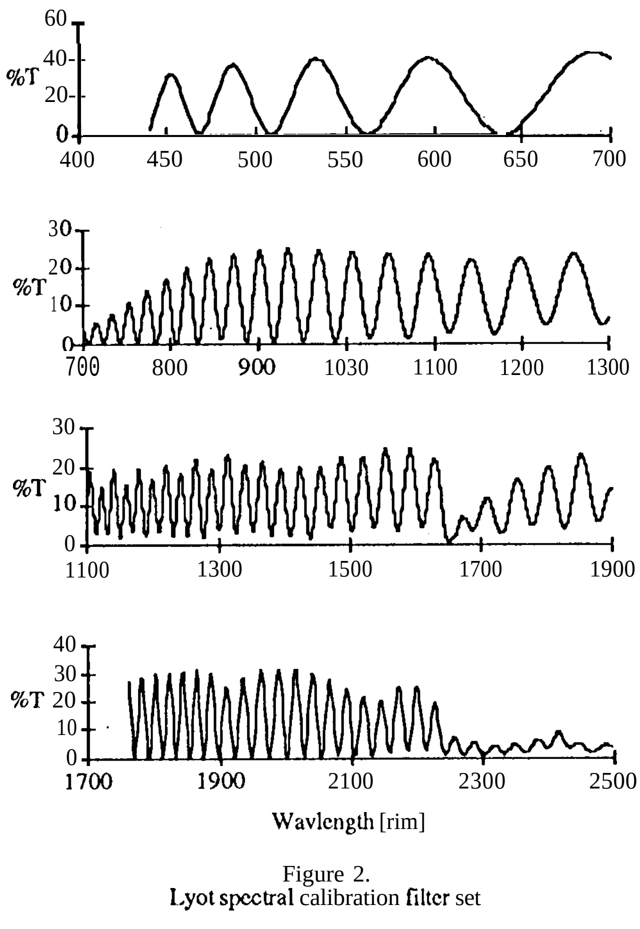

Figure 2.
Lyot spectral calibration filter set

Spectral Calibration Filters

Four ncw spectral filters have been designed for the onboard calibration source filter wheel. The filter wheel has been modified to accommodate the additional filters. The ncw filters consist of a birefringent material sandwiched between linear polarizers to make a single stage Lyot filter. The transmission of a Lyot filter varies as the cosine squared of one over the wavelength depending on the filter retardance. The four filters arc designed to have a period of approximately 20 nanometers at tJre short wavelength end of each AVIRIS spectrometers. 'Ibis insures that there will be sharply sloping spectral features across the entire 0.4 to 2.5 µm spectrum.

The spectral transmittance of the four filter set is shown in Figure 2. Measured data is shown for the first three filters which cover the 0.4 to 1.9 µm range, while the predicted performance is shown for the fourth 1.7 to 2.5pm filter. A temperature sensor placed on the filter wheel housing updates tJrc engineering telemetry once per second with a 0.3°C precision.

The data from the onboard calibrator is converted to spectral transmittance by dividing the Lyot minus Dark filter wheel spectra by the High minus Dark spectra. The sharply sloping transmittance features provide high sensitivity to spectral shifting inflight. Preliminary analysis shows that a 0.1 nm shift in spectral response is detectable using these filters.

REFERENCES

Chrien, T. G., R. O. Green, and M. L. Eastwood, "Accuracy of the Spectral and Radiometric Laboratory Calibration of the Airborne Visible/Infrared Imaging Spectrometer", Proc. SPIE Conference on Aerospace Sensing, Imaging Spectroscopy of the Terrestrial Environment, Orlando, Florida, 16-20 April, 1990.

Chrien, Thomas G., Michael L. Eastwood, Charles M. Sarture, Robert O. Green, and Wallace M. Porter, "Current Instrument Status of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)", Proc. Third AVIRIS Workshop, JPL Publication 91-28, pp. 302-313, 1991.

Chrien, Thomas G., R. O. Green, "Instantaneous Field of View Spatial Sampling of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)," Proc. Fourth JPL Annual Geoscience Workshop, JPL Publication 93-26, Jet Propulsion Laboratory, Pasadena, CA, 1993a.

Chrien, Thomas G., R. O. Green, C. M. Sarture, C. Chovit, M. L. Eastwood, and B. T. Eng, "Airborne Visible/Infrared Imaging Spectrometer (AVIRIS): Recent Improvements to the Sensor," Proc. Fourth JPL Annual Geoscience Workshop, JPL Publication 93-26, Jet Propulsion laboratory, Pasadena, CA, 1993b.

Green, Robert O., James E. Conel, Mark Helmlinger, Jeannette van den Bosch, Chris Chovit and Tom Chrien, "Inflight Calibration of AVIRIS in 1992 and 1993'', Proc. Fourth JPL Airborne Geoscience Workshop, JPL Pub, in press, 1993a

Green, Robert O., "Use of Data from the AVIRIS Onborrrd Calibrator," Proc. Fourth JPL Annual Geoscience Workshop, JPL Publication 93-26, Jet Propulsion Laboratory, Pasadena, CA, 1993b.

Vane, Gregg, T. G. Chrien, E. A. Miller, and J. H. Reimer, "Spectral and radiometric calibration of the Airborne Visible/lnfrarcd Imaging Spectrometer (AVIRIS)," Proc. SPIE, 834, (1987).

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